December 1997

DCIEM No.97-R-61

MEASURES OF THE DISCRIMINABILITY OF SYMBOL SHAPES

Sharon McFadden
Ben Bauer
Kelly McManus

Defence and Civil Institute of Environmental Medicine
P.O. Box 2000
1133 Sheppard Avenue West
North York, Ontario M3M 3B9

DEPARTMENT OF NATIONAL DEFENCE - CANADA

EXECUTIVE SUMMARY

The increase in the complexity of computer-based graphical information systems has resulted in a requirement for large symbol sets. To ensure that decisions are made with speed and accuracy, it is important for the symbols in such systems to be discriminated consistently and reliably. Studies on symbol discrimination usually find that discrimination is a function of the number and kinds of dimensions along which the symbols vary. However, the critical dimensions often vary from study to study. Some of this variability could be due to the wide range of conditions and methodologies used across studies. If this is the case, it is important to understand how different conditions and tasks influence the perceptibility and discriminability of symbols. The study reported in this paper addressed this problem. It compared the characteristics used in assessing the similarities of a set of symbols in a rating task with those used in picking out symbols in a visual search task. The former task is similar to the process used by a designer in selecting symbols while the latter is an important component of the actual tasks that an user carries out in locating information on a display.

Participants rated the similarity of ten geometric shapes using a paired-comparison task. Discriminability of these shapes was then examined using a visual search task where participants enumerated the number of occurrences of a particular target shape found in a display of distractors. The results were submitted to correlation and multidimensional scaling (MDS) analysis to examine the relationship between the similarity ratings and the visual search task. Based on the correlation analysis, subjective assessment can predict when two symbols will be highly discriminable. However in some cases, symbols rated as similar proved highly discriminable in the search task. The results of the MDS analysis suggested that, in the similarity rating task, participants differentiated the symbols primarily on their overall geometric shape. However in the visual search task, participants appeared to use other dimensions such as vertical height and symmetry in discriminating the symbols. These findings in conjunction with the results of other researchers suggest that context and task both may influence the features used in discriminating symbols. Suggestions are made for additional research that would evaluate the relevance of these two factors more thoroughly.

ABSTRACT

Participants rated the similarity of 90 pairs of symbols based upon ten geometric shapes. The discriminability of these shapes was then examined in a visual search task where participants enumerated the number of occurrences of a particular target shape found in a display of distractors. The results were submitted to correlation analysis and multidimensional scaling (MDS) analysis to examine the relationship between the similarity ratings and the visual search task. Based on the correlation analysis, subjective assessment can predict when two symbols will be highly discriminable. However in some cases, symbols rated as similar proved highly discriminable. The results of the multidimensional scaling analysis suggested that, in the similarity rating task, participants differentiated the symbols primarily on their overall geometric shape. However in the visual search task, participants appeared to use other dimensions such as vertical height and symmetry in discriminating the symbols. These findings in conjunction with the results of other researchers suggest that context and task both may influence the features used in discriminating symbols. Suggestions are made for additional research that would evaluate the relevance of these two factors more thoroughly.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

With the increasing complexity of computer-based display systems, larger symbol sets are being employed. In order to ensure that decisions made using these systems are carried out with speed, accuracy, and appropriateness, it is important for the symbols on displays to be discriminated consistently and reliably. In their investigation of redundant colour coding in visual displays, Bauer and McFadden (1997) noted that time to locate a target in a background of distractors varied significantly as a function of symbol shape. These differences in search time were somewhat unexpected given that, at the outset of the experiment, the symbol shapes had been perceived by the authors as clearly discriminable. However given the existing literature, such differences in discriminability might have been expected (e.g. Casperson, 1950; Treisman & Gormican, 1988; Duncan & Humphreys, 1989). Since shape is a primary coding dimension for symbols on many electronic display interfaces, it is necessary to understand the factors that can affect symbol discrimination as a function of symbol shape.

A wide range of studies have examined symbol discriminability. Many of these studies find that discrimination is a function of the number and kind of dimensions along which the symbols vary. However, the critical dimensions often vary from study to study. This is not surprising given that the studies varied in terms of the symbol sets used, the conditions that were studied and the methodologies employed (Medin, Goldstone & Gentner, 1993). To improve our ability to select suitable symbols for specific applications we need to understand how the characteristics used in discriminating symbols are affected by the conditions that will exist and the tasks that will be employed in these applications. The current study is an initial attempt to provide that information. It compares the shape characteristics used in assessing the similarities of a set of symbols in a similarity rating task with those used in picking out symbols in a visual search task. The former task is similar to the process used by a designer in selecting symbols while the latter is an important component of the actual tasks that an user carries out in locating information on a complex display.

Background

In an early study of shape discrimination, Casperson (1950) set out to identify the discrimination thresholds of six different geometric shapes and to relate their relative discriminability to functions of area, maximum dimension, and perimeter. His work showed that forms do, in fact, differ in their discriminability, and that any individual differences among participants making the discriminations are small when compared to the form differences. Using thirty different stimulus figures (six basic forms varied in five different ways), Casperson found that the best measure of discriminability was a function of form (e.g. area was the best measure of discriminability for triangles and ellipses, while perimeter was better for stars and crosses). However, across the six shapes, maximum dimension was the best dimension.

Eriksen (1952) believed that multidimensional differences between shapes might improve discriminability. He measured participants' speed of locating objects in a visual display when the target differed from the distractors on only one dimension (form, size, brightness, or hue) as opposed to when the target and distractors differed on two or more of these dimensions. However, he found that discriminability tended to vary more as a function of the particular dimension along which the target and distractors varied rather than the number of dimensions.

Treisman and Gelade (1980) examined the discriminability of multidimensional stimuli as well. They hypothesized that target recognition time should increase as a function of the number of dimensions that had to be processed before a decision could be made. Quinlan and Humphreys (1987), however, felt that the number of relevant features shared by targets and distractors was the critical factor in determining visual search speed in either a one- or two-feature similarity condition. They showed that search rates for a target that shared two features with a distractor were slower than search rates for a target sharing only one feature with the distractor. They also found that search rate depended on the similarity of the distractor items to one another as well as the dissimilarity between the target and the distractor items. Estes (1972) found similar results with a letter-detection task where the distractors were either similar (letters) or dissimilar (disks). When the background items were confusable with the target, responses were slower and less accurate than when the background distractors were nonconfusable.

The primacy of certain dimensions or features was examined in some detail by Treisman and Gormican (1988). They were interested in what dimensions were processed "automatically" by the visual system. By extension, symbols that varied along these dimensions should be more discriminable. They used a visual search task in which participants had to decide whether or not a target was present in a field of distractors. The number of distractors varied from trial to trial and the main measure of performance was the time taken to make a decision as a function of the number of distractors present. Response times for target present and target absent trials were scored separately. An indication of high discriminability was that the target immediately stood out among distractors, requiring no effort, regardless of the number of distractors. Such a phenomenon is known as perceptual "pop-out," evidenced by the way a particular item pops out in search tasks. It is shown by a flat curve, on both target present and target absent trials, when response time is measured as a function of number of distractors. In a more difficult search task, search times tend to increase as the number of distractors increases, with the slope for target absent trials being twice the slope for target present trials. Based on a large set of experiments, Treisman and Gormican concluded that dimensions such as colour, contrast, curvature, orientation, and length might function as primitives in the early visual system. However, the inclusion of some of these dimensions (such as contrast) depended on the degree of difference between the target and distractor. If the difference in contrast was relatively small, the target was not easily discriminated from its distractors.

Studies such as the ones above typically examine the discriminability of symbols that have been designed or selected to vary systematically along commonly used dimensions such as size, colour, orientation, or shape. Often only two distinct values along a given dimension are used. Symbol sets used in information displays are typically selected on the basis of their meaningfulness as well as their discriminability (Geiselman, Landee & Christen, 1982) and do not necessarily vary along well defined dimensions. Several different approaches have been developed to determine the factors affecting the discriminability of such sets. One approach is to analyse an arbitrary set of symbols, shapes or forms into a set of primitives and determine whether differences revealed by this analysis are reflected in human performance or subjective estimates of discrimination (Biederman, 1987). One problem with this approach is expressing a wide range of shapes in terms of a relatively small set of primitives. As well, much of this work has been aimed at understanding how we recognize common everyday objects rather than at symbol discrimination.

An alternative to this approach is to describe symbols in terms of their underlying spatial frequencies. The argument is that the recognition of forms and patterns can be predicted from the underlying spatial frequencies of which they are composed (Ginsburg, 1986). This approach can be used to describe arbitrarily complex images such as faces and scenes as well as simple geometric shapes and letters. It has proven useful in predicting the visibility of information on displays (Evans, 1993). However, it has been used most extensively to predict the detection and recognition of objects rather than to predict relative differences in discriminability amongst symbol sets.

A somewhat similar method that has proven very useful in automatic letter recognition is Fourier descriptors (Zahn & Roskies, 1972; Granlund, 1972). These descriptors can be used to describe the shape of any arbitrary closed contour by expanding the function relating cumulative arc length to local contour orientation into a Fourier series. In a recent study, Cortese and Dyre (1996) showed that differences in the Fourier descriptors of arbitrary shapes were consistent with the judged similarity of those shapes. However, the shapes had been generated to systematically vary in their Fourier components.

A more human-centered approach to determining the factors used in discriminating amongst arbitrary sets of symbols is multidimensional scaling (MDS). MDS seeks to represent the similarities between objects as distances in a low-dimensional space (Young, 1987). Mapping is based on measures of perceived stimulus similarity; perceived-as-similar stimuli are positioned close to one another in the multidimensional space, while perceived-as-dissimilar stimuli are positioned far apart. The measure of similarity may be direct subjective estimations of the similarity between pairs of perceived objects (Kleiss, 1995) or measures of discrimination such as reaction time or frequency of errors (Podgorny & Garner, 1979). The resulting spatial configuration is used to deduce stimulus properties which affect participants' perceptual judgment (Kleiss, 1995).

Multidimensional scaling has been employed in various areas. Kleiss (1995) submitted ratings of similarity between pairs of low-altitude visual scenes to MDS analysis to reveal the degree to which such scene properties perceived in real-world scenes were actually being perceived in simulated scenes. Paramei, Izmailov and Sokolov (1991) found that MDS applied to large chromatic differences created a visual colour space interpretable as three (red-green, blue-yellow, and white-black) colour opponent functions, represented as points on a sphere in three-dimensional space. Podgorny and Garner (1979) used MDS to compare the similarity structures of reaction times for fixed- and varied-target conditions of an interobject visual similarity task involving alphabetic stimuli. Work by Kuennapas (1967) and Kuennapas and Janson (1969) has applied multidimensional ratio scaling and multidimensional similarity analysis to studies of visual memory of both upper- and lowercase letters of the Swedish alphabet. Dimensions which have emerged from these studies include roundness, rectangularity, and vertical linearity.

Current study

As indicated above, a wide range of descriptors or dimensions have been advanced that could either be used by humans in discriminating amongst symbols or describe the factors that people use. Most of these descriptors have been evaluated on a restricted set of symbols. Moreover, different studies often employ different conditions and methodologies. Thus, it is not clear to what extent particular features or descriptors affect the visibility of symbols in an arbitrary display, or which of these features people actually use in discriminating or identifying symbols in a particular display. Currently, MDS appears to be the most useful method for determining the features that people actually use. However, it is not clear what conditions (e.g. symbol set, set size, task) may affect the features identified through the use of multidimensional scaling. If a feature space is not invariant under a wide range of conditions, it cannot be used to assess the factors (e.g. size, shape, colour) affecting discriminability unless the conditions under which the space was generated correspond closely to the actual situation in which the display will be used. Nor can a given feature space provide a basis for developing analytical methods for creating symbol sets.

The current study examined the impact of methodology on the relative discrimination of symbols in an arbitrary set. Discriminability of the symbols was assessed using a visual search task and a paired comparison similarity rating task.

The visual search task is widely used in investigations of the related issues of visual conspicuity (e.g. Bauer, Jolicoeur, & Cowan, 1996; Carter & Carter, 1981), visual attention (e.g. Duncan & Humphreys, 1989; Treisman & Gelade, 1980) and object perception (e.g. Brown, Weisstein, & May, 1992). Since an important component of many tasks using information displays is locating a specified target or piece of information, performance in a visual search task is seen as a good predictor of the conspicuity of a target. The typical visual search task involves an observer searching for one or more targets, which may or may not be present in a background of distractors. The number of distractor stimuli can vary from trial to trial. The primary measure of discrimination is the search time required to say that the target is or is not present or to count the targets.

A rating task has been used less frequently for estimating discriminability. It has the advantage that it can be carried out relatively quickly by large numbers of participants and thus allows the rapid assessment of the potential discrimination of large sets of symbols. Moreover, it is similar to the process used in the initial design of symbol sets which involves informal judgments of how similar or dissimilar the symbols are.

A few studies have estimated discriminability using both subjective and objective measures. Geiselman, Landee, and Christen (1982) had participants rate the similarity of members of a set of military symbols. They then compared the similarity rankings with different analytical analyses of the components underlying the symbols. The results of this phase, which showed that participants compared symbols on the basis of their configural components rather than on simple features, were then used to predict the visibility of a new set of symbols. The accuracy of this prediction was evaluated using a visual search task. They concluded that there was good correspondence between the predicted discriminability and actual discriminability. This finding suggests that the features used in picking out a symbol in a background of distractor symbols are similar to those used in ranking their similarity.

Tomonaga and Matsuzawa (1992) investigated similarities in a set of figures using a similarity rating task and a match-to-sample task. In the latter task, participants were required to indicate which of two comparison stimuli was identical to a sample stimulus presented prior to the onset of the comparison stimuli. The authors subjected the results for both tasks to a MDS analysis and found many similarities in the results of the two dimensional solutions for the two tasks. However, there were also some differences. These difference were not explored, nor was any analysis of the meaning of the dimensions carried out.

A more direct comparison of methodology was carried out by Podgorny and Garner (1979) using upper case letters as stimuli. They compared similarity ratings with a match-to-sample task in which participant had to indicate whether the current symbol was identical to one presented at a previous point in time. They were interested in whether reaction time was predictive of perceived similarity. They found that the location of the letters in a two dimensional space based on the reaction time data correlated highly with their location in a two dimensional space based on the similarity ratings.

The above studies provide some evidence of a consistency in discriminability across methods. However, the study by Geiselman et al (1982) did not directly compare the two methods and the latter two studies did not examine the underlying features that might have been used by participants in discriminating amongst the symbols. Moreover, the match-to-sample task does not necessarily assess the visibility of a symbol. Rather, participants are comparing the similarity of an existing symbol to one presented previously. The current study compares a similarity rating task with a visual search task in which participants were asked to count the number of instances of a target symbol in a background of distractor symbols. To allow more direct comparison with the rating task, the distractor items on a given trial were identical.

The symbols used in this study were taken from the International Hydrographic Organization Electronic Chart and Display Information System (IHO ECDIS) Presentation Library (IHO, 1995) which contains a collection of maritime symbols representing beacons, buoys, buildings, and other markers or hazards. Since the symbols were a subset of an actual symbol set, it is possible to examine discrimination of the symbols within the subset chosen and potentially within the larger set. There is also the possibility of comparing the results of this study with the visibility of the symbols in the context of the ECDIS display. Finally, these symbols could be subjected to Fourier analysis using either Fourier descriptors (Zahn & Roskies, 1972) or two dimensional spatial frequency analysis (Maddox, 1979).

METHOD

Participants

Twelve participants, 6 females and 6 males with normal or corrected-to-normal vision, participated in the study and were compensated according to Defense and Civil Institute of Environmental Medicine (DCIEM) guidelines. Participants were DCIEM military and civilian personnel and individuals from outside DCIEM. All participants had normal colour vision as assessed by the Farnsworth-Munsell 100-Hues test. The mean age of the participants was 28 years (range 20-40) years.

Apparatus

Stimuli were presented on a Macintosh Quadra 800 computer with a RasterOps Paintboard Li driving a RasterOps 20 inch colour monitor (model 2075RO). Responses were obtained via the numeric keypads on the computer keyboard. Chromaticity and luminance values were measured using a Minolta CS-100 Chromameter.

Stimuli

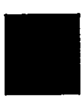
The stimuli were ten geometric shapes taken from the International Hydrographic Organization Electronic Chart and Display Information System (IHO ECDIS) Presentation Library. This 10 item subset of ECDIS symbols contained only closed, filled polygons of unitary structure. Each shape, its identifier, maximum coordinates, and visual angles are shown in Table 1[1]. For ease of reference, the symbols will be referred to by their general shape or by the

---

[1]The Cartesian coordinates for the set of ten closed ECDIS shapes are found in Appendix A.

letters a-j. The shapes, as presented on the displays, are proportionally the same as in Table 1. Stimuli used in both the rating and visual search tasks were identical such that a given shape appeared at the same size and colour in both tasks.

Table 1: Maximum width, height and degrees of visual angles for each symbol

Symbol	Identifier	Width (mm)	Height (mm)	Width (degrees)	Height (degrees)
	a	3	7	0.29	0.67
	b	3	10	0.29	0.95
	c	7	7	0.67	0.67
	d	6	6	0.57	0.57
	e	7	7	0.67	0.67
	f	4	4	0.38	0.38
	g	6	10	0.57	0.95
	h	10	10	0.95	0.95
	i	8	4	0.76	0.38
	j	4	11	0.38	1.05

At all times during the experiment, the screen background was a desaturated blue (CIE 1931 chromaticity (x=.240, y=.260)) at 32.8 cd/m^2. The shapes were displayed in red (CIE 1931 chromaticity (x=.480, y=.300)) at 14.7 cd/m^2. These particular colours were based upon colours used in ECDIS, the former being DEPMS, the latter being CHRED (IHO, 1995).

Displays - Similarity Rating Task

The displays contained 2 items side by side, displayed in the centre of the screen (horizontal separation was approximately 1 degree). On the bottom left hand side of the screen, a reminder of the rating scale was presented in white (0=least similar; 99=most similar).

Procedure - Similarity Rating Task

Given the 10 items in the symbol set, there were 90 possible symbol pairings (as a symbol was not presented with itself). Participants performed 5 replications of each of the 90 combinations. Order of presentation of combinations was randomized within each set of 90 such that the same item appeared as the left or right item in no more than two consecutive trials.

Before beginning the rating task, participants read an instruction sheet that asked them to consider the similarity of the pairings of shapes. They were asked to think about how likely they would be to confuse the two members of each pair. Participants were instructed to rate the pairs only in the size and direction in which they appeared on the display, being careful not to rotate or shift them in any way.

Prior to the 5 replications, a sample screen illustrating all 10 items was presented along with instructions to view all the items to consider how to use the full range (0-99) of similarity across all pairings. This display remained available until the participant signaled with a keystroke to continue. Participants were instructed to respond according to their first impression of each pair, and not to concentrate on a pair for too long.

Displays - Visual Search Task

The displays contained 54 items arranged in the cells of an imaginary 6 (vertical) by 9 (horizontal) array. Each item was randomly offset by several pixels in order to break up the regularity of the display. In each display, there were 6-9 instances of a single target item, with the remaining items being instances of a single distractor item. The maximal array subtense was approximately 21.8 by 21.8 degrees. The background display was approximately 26.6 (vertical) by 34.2 (horizontal) degrees. Display items were spaced approximately 2.3 degrees (horizontal) and approximately 4.0 degrees (vertical) apart. As in the rating task, a total of 90 target-distractor pairs were tested.

Procedure - Visual Search Task

For each of the 90 target-distractor combinations, a run of 28 trials was generated. These 28 trials consisted of 4 practice trials and 24 experimental trials. The 24 experimental trials represent the crossing of two factors: the first being the number of targets (4 levels, 6-9) and the second being six replications each of the four levels of target quantity.

Testing of the 90 runs was performed in 4 sessions with 22 runs in both the first and fourth sessions, and 23 runs in both the second and third sessions. The order of presentation of the 90 target-distractor combinations was randomized, subject to the constraint that the same item could not serve as the target or distractor in more than 2 consecutive runs. Over the 4 sessions, participants responded to (90 X 28) 2520 counting trials.

Prior to each run, a screen specifying the target and distractor item for that run was presented. This display remained on until the participant signaled with a keystroke to continue. Then the 4 practice trials were presented with feedback in the form of a plus for a correct response or a minus for an incorrect response, followed by a report on the overall performance for those four practice trials. Then the 24 experimental trials (again, with trial- by-trial feedback) were presented. Participants were told that there would be 6 to 9 target items per trial, and to enumerate the targets without manual aids such as counting on the screen or on their fingers. Participants were instructed to enter their count using the numeric keypad to the right of the keyboard, and to make their responses as quickly and accurately as possible. Displays remained on the screen until the response was made. Short breaks were permitted between runs at each participant's discretion.

General Procedure

Participants were tested individually. They first read a page of general instructions which described the experiment and then read and signed an informed consent form. Each participant's colour vision was tested using the Farnsworth-Munsell 100-Hues test (with the exception of two participants who had been tested several months earlier as part of another experiment). Three participants exhibited elevated but apparently random error patterns on this test and were subsequently retested. All three participants showed acceptable results on the second testing.

The colour vision screening was followed by the five runs of the rating task. Participants were seated (unrestrained) approximately 60 centimeters from the computer monitor which was centered at eye level. The room was dimly illuminated by two overhead incandescent light bulbs. There were approximately 13 lux falling on the keyboard, and approximately 4 lux falling on the monitor.

This first session took approximately one hour. In the four subsequent testing sessions of approximately one hour each, participants responded to one quarter of the total counting trials. Sessions were generally run on separate days, but some participants ran two sessions on a single day, with each session separated by at least three hours. At the end of the fifth session, any questions regarding the experiment were answered.

RESULTS

Data (both rating and visual search) from two participants were excluded because of a large number of zero responses on the rating task.

Similarity Ratings

Data files were examined and anomalous responses (greater than 99 or alphabetic) removed. The responses for each pair of symbols were then averaged across the five runs and a matrix of the mean similarity ratings was generated for each participant. Table 2 shows the average of these matrices.

Table 2: Mean similarity ratings (0-99) for each symbol pair

Distractors	Targets									
	a	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**
a	0	63	36	58	22	76	44	65	18	45
b	63	0	31	34	12	35	44	37	22	66
c	35	26	0	49	14	27	56	34	24	17
d	61	31	46	0	29	58	35	59	27	21
e	22	17	19	29	0	25	13	23	41	23
f	74	38	31	58	26	0	19	72	35	16
g	47	41	61	42	12	19	0	18	20	46
h	62	34	36	61	26	70	21	0	15	10
i	18	24	27	31	45	34	20	13	0	27
j	45	66	23	18	25	16	44	11	31	0

The average similarity ranking ranged from 10 for pair **hj** to 76 for symbol pair **af** indicating that on average participants used most of the available range. The similarity in the upper and lower halves of the matrix in Table 2 indicates that participants were consistent in their rankings. However, as shown in Table 3 the range actually used differed widely across participants. These difference could mask similarities between the search and ranking data.

Table 3: Range of ratings used by each participant.

Participant	1	2	3	4	5	6	7	8	9	10
Mean	58	19	54	61	31	22	13	25	32	42
Std. Dev.	20	19	19	20	28	25	10	28	18	17
Minimum	18	1	19	18	0	1	3	0	9	9
Maximum	97	92	95	92	95	89	57	99	83	83

Visual Search

For each of the 90 pairs, there were 24 responses based on six trials at each of the four possible number of targets. On average, there were less than two errors per target/distractor pair and the number of errors was highly correlated with response times. Thus, no further analysis of the error rates was carried out. For the visual search times, data reduction was performed in the following manner. All trials with an incorrect enumeration were eliminated. Then each response time per trial was converted to a ms/target in order to collapse across trials with different numbers of target items. Next the data were screened for outliers (See Van Selst and Jolicoeur, 1994 for further examination of this technique for outlier analysis) and then the remaining data were averaged across trials to produce a single measure for each participant for each target/distractor pair. Less than two per cent (371 of 20518 observations) of the data were excluded as being outlying observations.

Figure 1 shows the log mean search times and Table 4 the mean search times in ms/target for each of the ten symbols collapsed across targets and also collapsed distractors. As can be seen, some symbols were easy to find (e.g. **h** and **e**), while others (e.g. **a** and **b**) were comparatively difficult to locate among the distractors. At the same time, certain symbols appeared to more consistently interfere with detection (e.g. **b** and **g**). A within-participant ANOVA found that both the main effect of target ($F(9,81)=78.13$, $p < 0.001$) and distractor ($F(9,81)=84.18$, $p < 0.001$) and the interaction ($F(71,639)=40.02$, $p<0.001$) were significant.

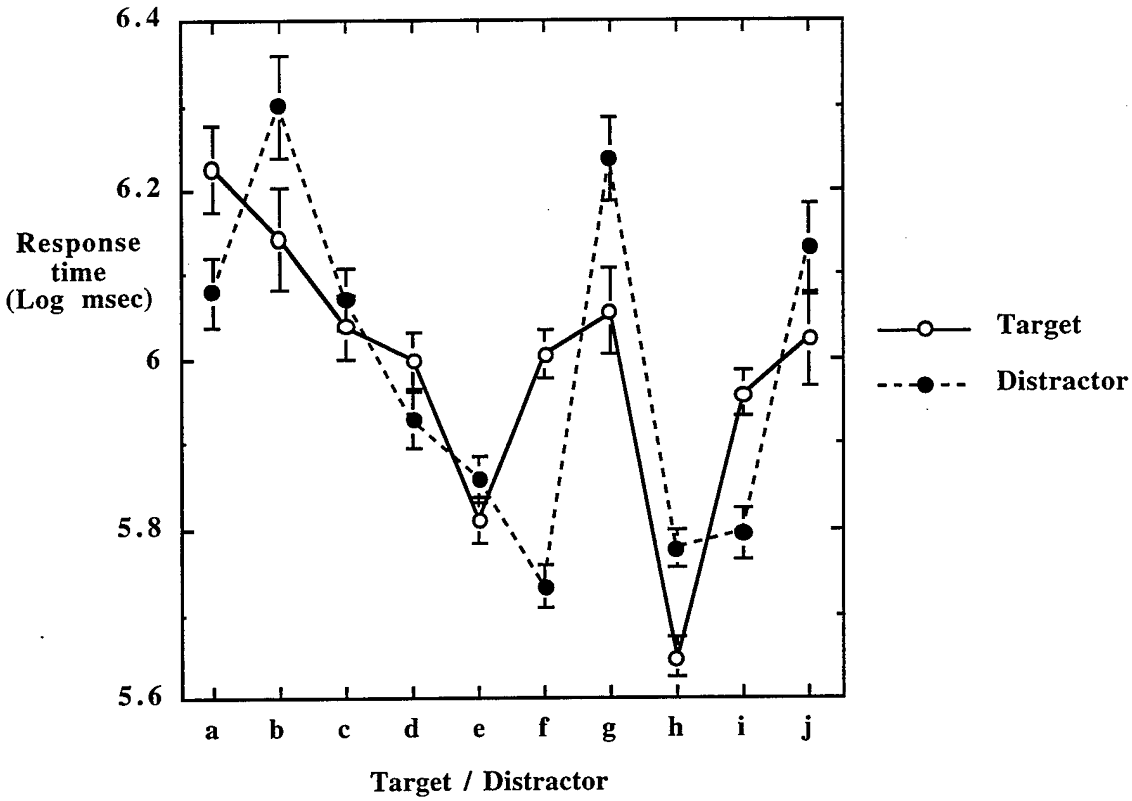


Figure 1: Log mean search time (ms/target) for ten symbols collapsed over all the distractors and collapsed over all the targets.

Log response times are shown in Figure 1 to allow a comparison of standard error across the different targets and distractors. Targets or distractors with short response times on average tended to have consistent response times and those with longer average response times tended to show larger variability. The response times for individual target distractor pairs are shown in Table 4. As can be seen, none of the targets were consistently difficult to detect across distractors. Another feature of the matrix is that if a target was easily discriminated from its distractors, it also tended to produce short response times when it served as a distractor (e.g. **h** and **e**).

Table 4: Mean search response times per item for each target-distractor pair

Distractors	Targets										Distractor Mean
	a	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	
a	.	849	403	370	324	622	482	319	362	518	473
b	1204	.	483	461	375	376	935	303	387	1215	638
c	567	444	.	600	325	432	676	295	428	372	460
d	400	306	620	.	377	379	351	325	473	319	395
e	366	309	351	427	.	416	293	298	502	303	363
f	421	318	315	291	289	.	301	262	368	293	318
g	716	933	793	574	350	329	.	278	400	745	569
h	343	300	311	402	336	338	309	.	320	300	329
i	329	314	356	320	424	494	289	268	.	292	343
j	770	1200	420	359	294	403	698	268	349	.	529
Target Mean	569	553	451	423	344	422	482	291	399	484	.

Unlike the symmetry in the similarity ratings data, the search response data are often asymmetric. This can usually be attributed to a symbol being less effective as a distractor. For example, response times for symbols **a** and **f** tended to be longer when they served as target than when they served as distractor. On the other hand, symbols **b** and **g** tended to have longer response times when they served as distractors than targets, but this was primarily due to the proportionally longer response times when they were the distractor and **a** was the target than vice versa. Such asymmetry, however, is not unexpected. It has been well documented that targets and distractors are not interchangeable in terms of search performance (Treisman and Gormican, 1988; Nagy & Cone, 1996).

Relationship Between Similarity Ratings and Visual Search

The primary purpose of the study was to compare the similarity rating and the visual search tasks in order to determine if there was a relationship between the two. One way to examine this relationship is by means of correlation analysis. The Pearson correlation between the ratings and the response times was $r=0.28$, $p < .01$. Although, significant, it is relatively low. As stated earlier, this could have been due to the wide variability in the ratings used by the participants. An examination of the correlation coefficients for the individual participants supports this hypothesis (Table 5). Some participants showed a relatively strong correlation between their similarity ratings and their search performance (e.g., correlations of above $r=0.60$), while other participants showed relatively weak correlations (as low as $r=0.12$). Comparing Tables 3 and 5, it can be seen that participants with low correlations tended to have a low average rating and use a small range of ratings. However, the reverse is not necessarily the case (e.g. participants 2 and 3).

Table 5: Correlation between similarity ratings and search times by participant

Participant	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Correlation	0.61	0.37	0.32	0.48	0.50	0.23	0.15	0.12	0.62	0.64
Level of significance	*	*	*	*	*	ns	ns	ns	*	*

Note: * = $p < 0.01$
ns = not significant

An alternate or additional explanation is suggested by Figure 2. Items with short search times tended to be rated as dissimilar with some clear exceptions. Participants rated the large square (h), the small square (f), the rectangle (a) and the parallelogram (d) as similar to each other. However, in the search task all these symbols tended to be discriminated easily from each other.

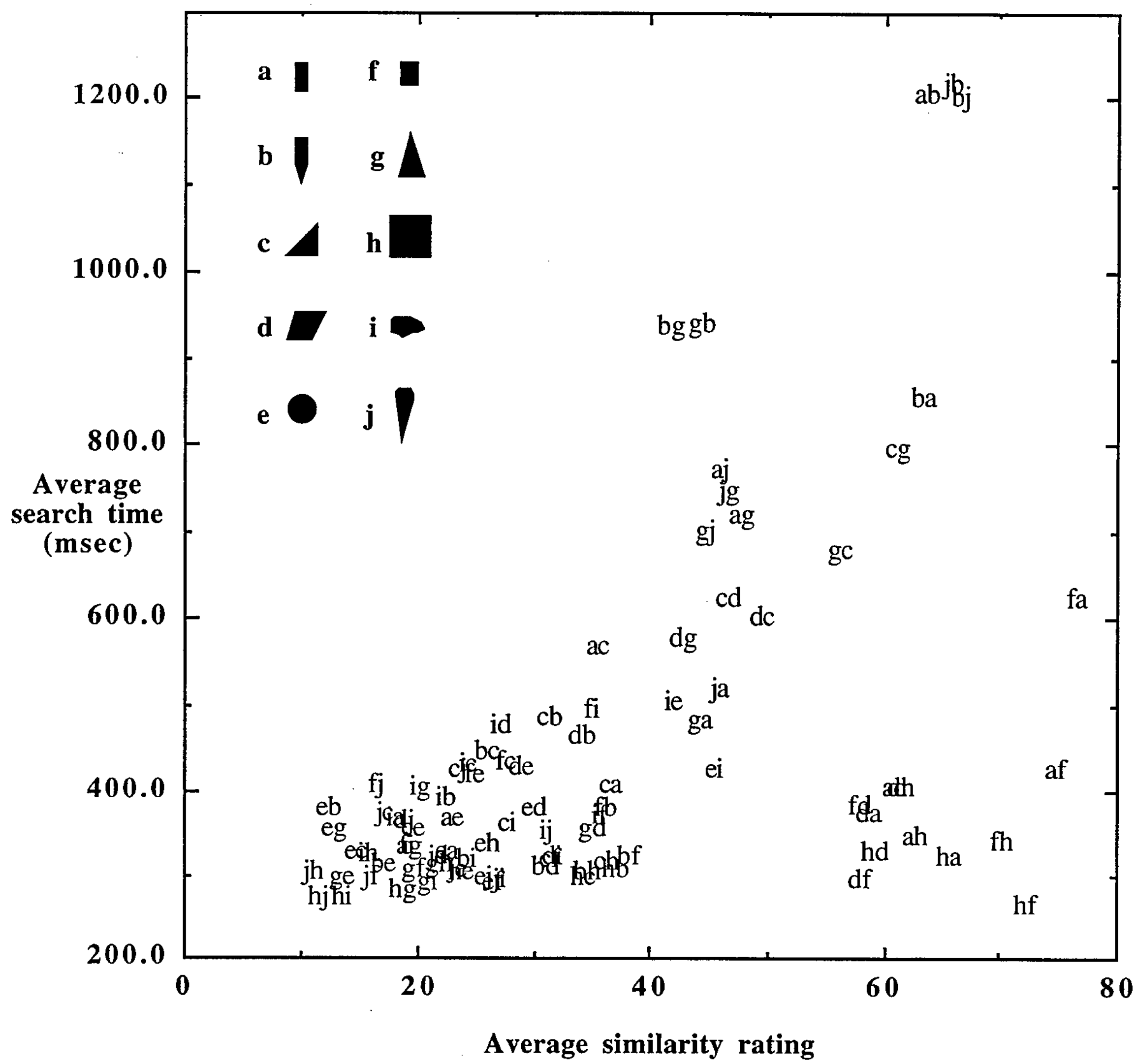


Figure 2: Correlation between visual search response times and similarity ratings for each target paired with each dissimilar distractor symbol. The actual values are shown in Tables 2 and 4.

Multidimensional Scaling

In addition to comparing the results of the two tasks directly, the underlying features that could have been used by the participants in the different tasks were compared using multidimensional scaling,. A weighted Euclidean model was fit to the response matrices for each task using the MDS procedure in SAS® (1992). The ratings were defined as interval data and a matrix partition was used because the data for different participants could not necessarily be meaningfully compared (Young, 1987). The response times were treated as ratio data and a single partition was used. Both analyses were carried out on a square (rather than a triangular) matrix because the matrices were asymmetrical.

An initial examination of the symbols indicated that a two dimensional fit was justified, and a three dimensional solution was also possible, in that there are at least four separate dimensions which could be hypothesized to exist within the space (for example, size, symmetry, aspect ratio (height, width), and directionality). Following the recommendation of Davison (1983), solutions were obtained for 1 to 6 dimensions. The MDS procedure provides several measures of the fit of the data to a particular solution. For a weighted Euclidean model, either the badness-of-fit criterion (or stress value) or the correlation between the data and the transformed distances can be used (Davison, 1983). With the first measure, the lower the value is, the better the fit; with the second, the higher the value, the better the fit. Figure 3 shows the values determined for these two criteria as a function of the dimensionally of the solution for the two tasks[2].

The standard method for selecting the appropriate solution is a clear elbow or knee in the plot of fit versus dimensionality of the solution. The absence of a clear elbow and a relatively high correlation indicates a one dimensional solution. As can be seen in Figure 3, there is no clear bend in either plot for the rating data and the correlation is close to 1 for all solutions. This would suggest that a one-dimensional fit is appropriate. In contrast to the rating results, there is a clear bend in the plots for the search data suggesting that a two and possibly a three dimensional fit would be most appropriate for these data.

---

[2] The actual distances for one, two and three dimensional solutions for each task are tabulated in Appendix B.

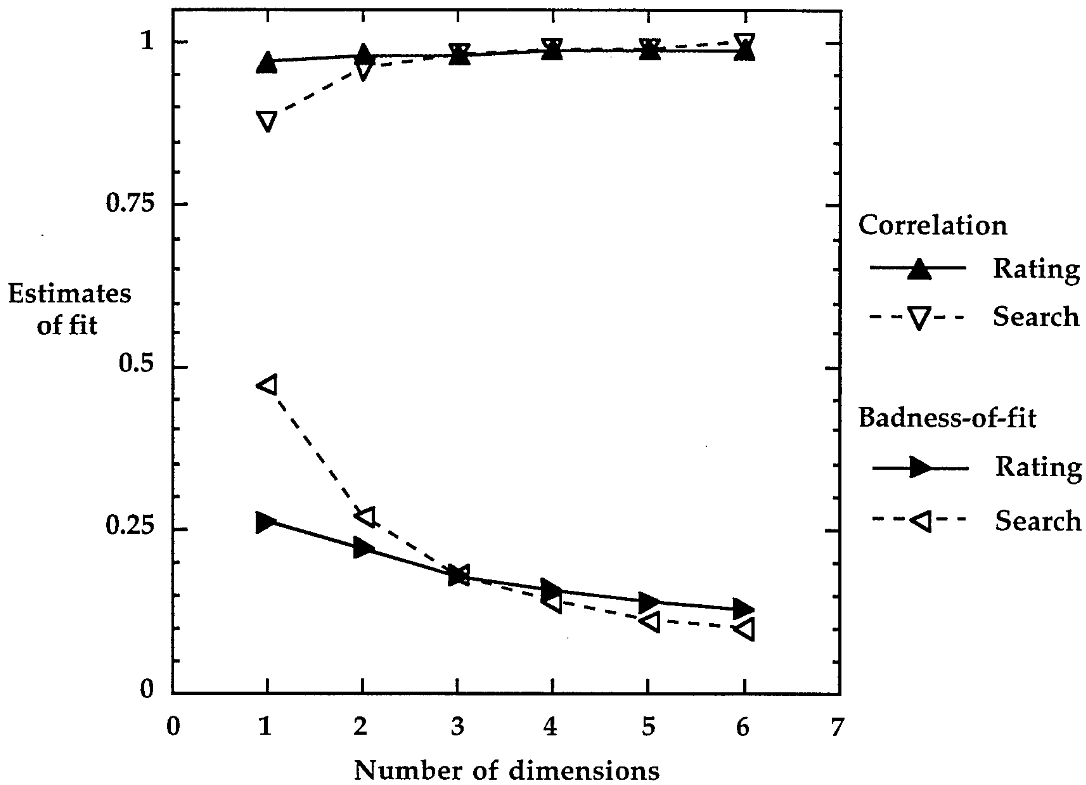


Figure 3: Two measures of the fit to the rating and search data for one to six dimensional solutions.

An examination of the one dimensional space for the rating data (Figure 4) shows that the symbols tend to be differentiated according to their overall or dominant geometrical shape with triangular objects such as **g** lying at one extreme, rectangular objects in the middle, and circular objects at the other extreme. The one dimensional solution for the search data (Figure 4) is somewhat similar. The primary difference is with the location of the circle (**e**), the small square (**f**) and the rectangle (**a**). The latter two tend to be grouped with the large square (**h**) and the parallelogram (**d**) in the rating space. In the search space, **h** is not closely associated with either **f** or **a**. These differences tend to be consistent with the picture presented in Figure 2.

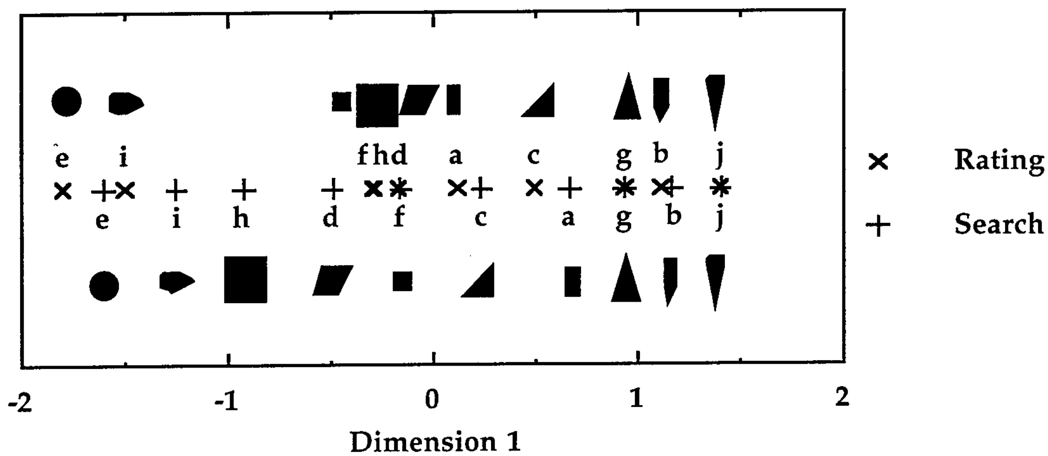


Figure 4: Location of symbols in a one dimensional space based on the similarity ratings and on the visual search response times.

As stated above, a two or three dimensional solution is probably more appropriate for interpreting the search data. Figure 5 shows the two dimensional solution for search and rating data to allow for comparison. In both cases, the first dimensions are similar to the one dimensional solutions. For the rating data, the second dimension is similar to the first dimension in that it differentiates between objects that could be perceived as being similar to **h** (the large square) or **e** (the circle). The second dimension of the two dimensional solution to search data, on the other hand, appears to differentiate between symbols with a large diagonal element and large horizontal extent such as **d** and **c** and symbols such as **a** and **f** which have neither.

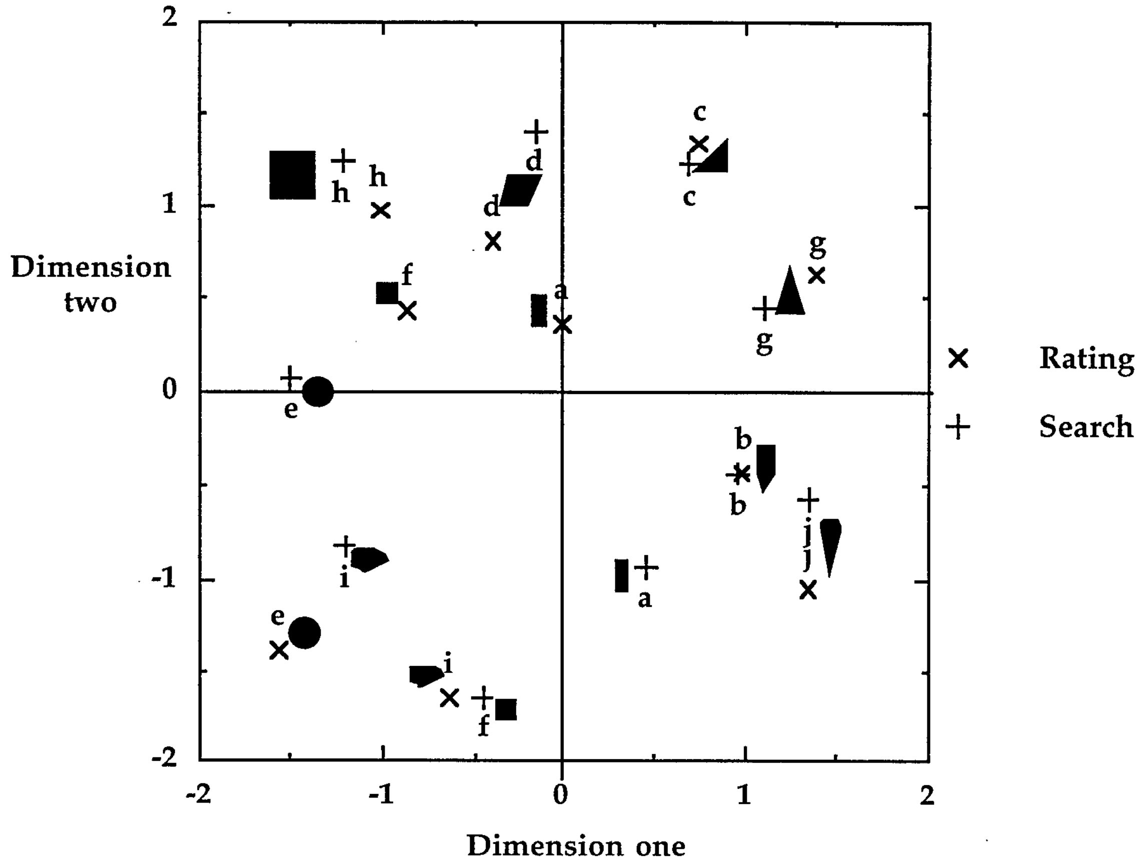


Figure 5: Location of symbols in a two dimensional space based on the similarity ratings and on the visual search response times.

Unlike the one and two dimensional solution, the first dimension in the three dimensional solution (Figure 6) would seem to be vertical height with tall objects clustered toward one side and symbol **i** at the other extreme. An exception is symbol **d** which tends to be clustered with **g** and **b** instead of **a**, **c** and **e** which have a similar vertical extent. A second exception is **f** which is clustered with **a** and **e** but has a vertical extent similar to **i**. Dimension two has symbols with a large 45 degree angle at one extreme and symbols with a small cross section at the other extreme. However, the ordering of the remaining symbols is not necessarily consistent with this interpretation. Finally the third dimension discriminates targets that tend to differ in their average length and width (**g**, **b**, **j**, and **c**) from those that do not (**f**, **h** and **c**), or in their degree of symmetry.

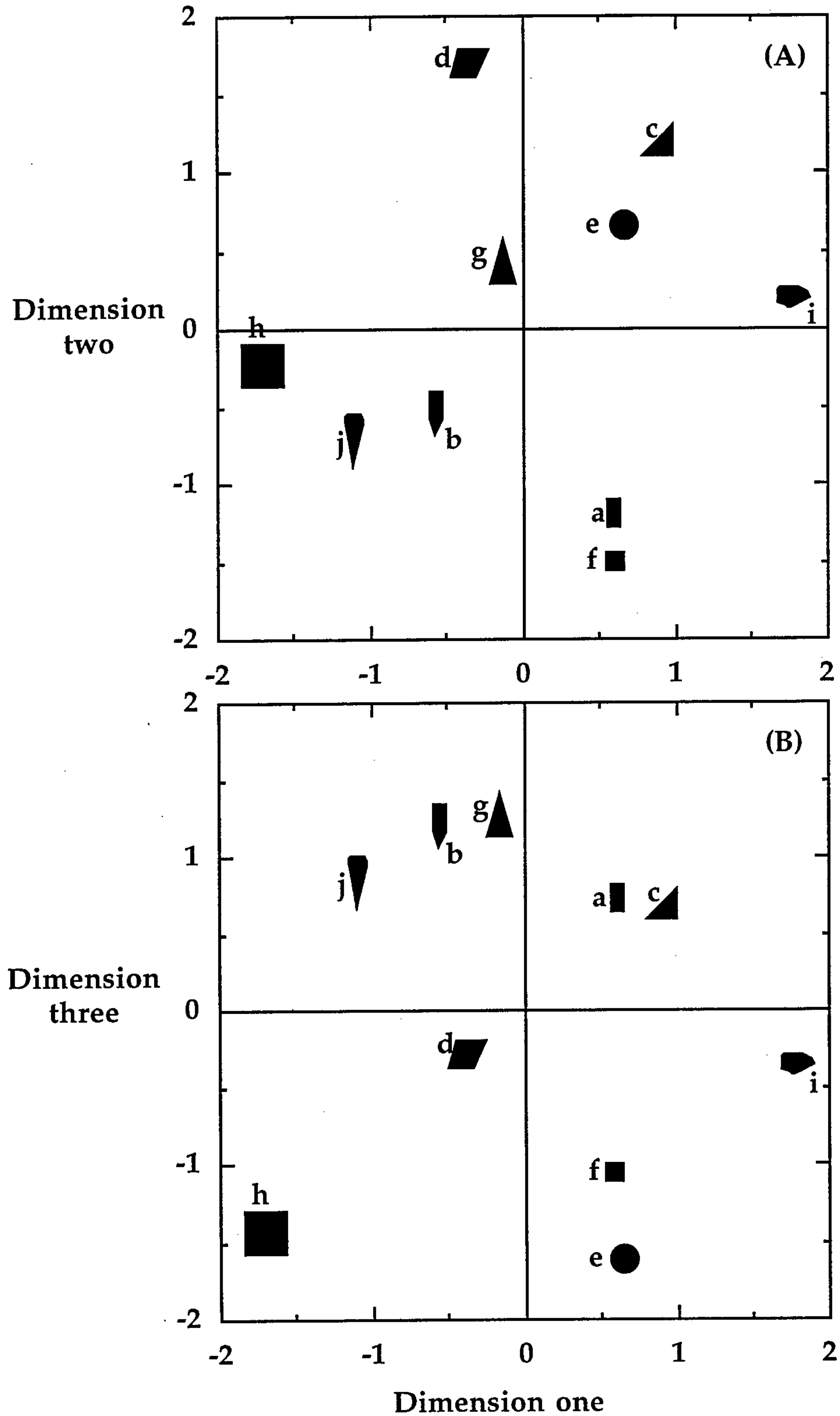


Figure 6: Location of symbols in a three dimensional space based on the visual search response times. Dimensions 1 and 2 are shown in A and 1 and 3 in B. The letters mark the actual locations of the symbols in the space.

DISCUSSION

The symbols used in this experiment were a subset of the symbols specified in the ECDIS standard on colour and symbols. Thus, they had already been chosen or designed to be discriminable from one another and from other members of the larger set. This was reflected in the similarity ratings and in the search response times. The highest average similarity rating in Table 2 was 76 and that was after the data from the two participants that gave most of the pairs a rating of zero had been removed. Average search times per item were in some cases less than 300 msec. In fact, the counting task was chosen because a preliminary experiment using a standard yes/no task was insensitive to differences in discriminability. When the counting task was used, clear differences in discriminability were identified as shown in Table 4 and Figure 1. Moreover, most participants were able to rate the similarity of each pair of symbols in a consistent manner. Across participant similarities were less consistent, but a clear pattern emerged. Differences lay mainly in the participants' use of the scale. Some made use of the whole scale. However, a few tended to see most of the symbols as highly dissimilar.

The intent of the investigation was to determine whether similarity ratings of a given symbol set are related to difficulty in discriminating members of that set from each other in a visual search task. That is, if participants perceive two symbols as being highly similar, will this be reflected in a longer visual search time (or "hard" search)? If participants perceive another two symbols as being quite dissimilar, will this be reflected by an "easy" search? If the similarity ratings are predictive of search times, it suggests that this subjective measure of similarity may be adequate for discriminable symbol selection. However, if there are discrepancies among individuals' ratings and search times (e.g., they may rate a pair of items as being dissimilar, but find difficulty in distinguishing the two items in the search task), it indicates that subjective analysis alone may not be adequate for developing a discriminable symbol set.

Based on the correlation analysis, it would appear that subjective assessment of similarity primarily predicts when two symbols will be highly discriminable. Targets rated as highly dissimilar (less than 40), rarely had a long response time; However, some targets rated as similar were discriminated easily. Participants rated symbol pairs that were similar in geometric form but differed in size or height/width ratio as similar. However, those differences tended to make them relatively discriminable.

The picture presented in Figure 2 is substantiated by the MDS analysis. An examination of the fits to the rating data suggests that the participants are differentiating the symbols primarily on their overall geometric shape — triangular versus rectangular versus circular. Since most of the symbols used in this study were either simple geometric shapes or slight variants, it is not surprising that people grouped them in that way.

On the other hand, the MDS analysis of the search times suggests that simple dissimilarity in underlying geometric shape is not necessarily a good predictor of how discriminable the symbols will be. The one dimensional fit, which is similar to the one dimensional fit for the rating data, has a relatively high badness-of-fit value. The three dimensional solution suggests that observers are discriminating the symbols instead on more basic characteristics. The first dimension, in which the symbols are differentiated on the basis of vertical height could correspond to spatial frequency. The second dimension tends to differentiate the symbols on the basis of whether they have a strong non vertical and non horizontal component or not. The third dimension corresponds to symmetry.

Overall, these results suggest that rating the similarity of the symbols will probably result in discriminable symbols as measured by our search task. However, reliance on this method may result in failure to consider other dimensions or features that may enhance discriminability as well. The effect may be that symbols are grouped in unexpected ways. For example, if the designer creates two subsets of symbols that differ in whether or not they have an 'X' in them and half of each subset is asymmetrical, users may group them more along the symmetry/asymmetry dimension than the X/no X dimension.

The differences between the rating and search data are somewhat inconsistent with a previous study by Geiselman, Landee, and Christen(1982). They found a strong correlation between search times and a discriminability index that they had derived from similarity ratings. Based on an analysis of their similarity ratings, they concluded that discriminability was a function of the number of configural elements a pair of symbols had in common. In many cases, their configurable elements corresponded to geometric form. Thus in this way, the results for their similarity rating would be consistent with ours. The differences in the results for the visual search conditions could be due to the fact that their symbols were usually combinations of these basic configural elements while ours were closer to the actual basic elements. Thus, their participants were asked to differentiate not between a triangle and a square but between a square with a triangle and one with an X. Another reason for the difference may be that their symbols did not tend to vary in height, width, and symmetry as ours did. Finally, their participants had to locate the symbol in a background composed of all of the remaining symbols. That type of visual search task may be conceptually closer to the similarity rating task in that participants must take into account the whole symbol set in reaching a decision.

The results of a study by Tomonaga and Matsuzawa (1992) are closer to the current study. Their set included symbols that varied in their size, geometric form, and whether or not they were filled, as well as shaped or curved lines. They examined MDS analyses of similarity ratings and response times in a match- to-sample task. The results indicated that stimuli tended to be differentiated by size and whether they were filled or unfilled as well as by geometric form. Thus, a small filled circle was located close to a small filled diamond shape and was widely separated from a large open circle. A two dimensional fit to the data indicated that participants tended to differentiate the symbols on the basis of size and filled versus unfilled in both tasks. There were also some differences between the results for the rating task and the results for the match-to-sample task. However, these differences were not explored in any detail in their paper. Moreover, they did nor report the results for any higher dimensional fits despite the relatively high stress values associated with the two dimensional fits.

Future Research

This study used relatively small set of symbols and employed a relatively simple paradigm. The advantage of this approach was that it kept both tasks to a manageable size and it was possible to determine which symbols were being confused with which. However, we are ultimately interested in being able to predict the visibility of these and other symbols in the context in which they will be used.

One step in that direction would be to assess the visibility of these symbols when presented in a background composed of the remaining symbols. Such a task would not only be more realistic , it would be closer to the visual search task used by Geiselman et al. As discussed above, the difference between the results for the similarity ratings and the visual search task in the present experiment may have been due to the type of visual search task used.

A second step would be to compare the relative similarity and discriminability of these symbols in the context of a more heterogeneous symbol set. We need to know to what extent context defines the visibility of a given symbol and the features used in discriminating that symbol from others. Our results coupled with those of Geiselman et al and Tomonaga and Matsuzawa suggest that the composition of the symbol set can have a strong influence on the underlying features that people use in rating symbol similarity. Since the symbol set in this study is part of a much larger set, it would be possible to investigate the discriminability of each symbol in a different context and within a larger stimulus set.

CONCLUSION

This initial study sought to improve our understanding of the factors that govern the discriminability of a set of symbols using a similarity rating task and a visual search task. The results for the two tasks were compared using correlation analysis and multidimensional scaling. Although there were some similarities between the results for the two tasks there were clear differences. In the similarity rating task, participants appeared to categorize the symbols in terms of overall geometric shape. In the visual search task, other factors such as size, orientation and symmetry appeared to be important as well. The findings suggest that perceived similarity may not be the best predictor of the speed with which specific symbols will be identified in a search task. These results in conjunction with previous results suggest that context and task may both influence the features used in discriminating symbols. Further studies are required to evaluate the role of these two factors in more detail.

REFERENCES

Bauer, B., Jolicoeur, P., & Cowan, W. B. (1996). Visual search for colour targets that are or are not linearly-separable from distractors. *Vision Research*, **36**, 1439-1465.

Bauer, B. & McFadden, S. (1997). *Redundant coding in visual search displays: Effects of shape and colour*. DCIEM No. 97-R-04, North York, Ont: Defence and Civil Institute of Environmental Medicine.

Biederman, I. (1987). Recognition-by-components: A theory of human image understanding. *Psychological Review*, **94**, 115-147.

Brown, J. M., Weisstein, N., & May, J. G. (1992). Visual search for simple volumetric shapes. *Perception & Psychophysics*, **51**, 40-48.

Carter, E. C. & Carter, R. C. (1981). Color and conspicuousness. *Journal of the Optical Society of America*, **71**, 723-729.

Casperson, R. E. (1950). The visual discrimination of geometric forms. *Journal of Experimental Psychology*, **40**, 668-681.

Cortese, J. M. & Dyre, B. P. (1996). Perceptual similarity of shapes generated from Fourier descriptors. *Journal of Experimental Psychology: Human Perception and Performance*, **22**, 133-143.

Davison, M. L. (1983). *Multidimensional Scaling*. New York: Wiley & Sons.

Duncan, J. & Humphreys, G. W. (1989). Visual search and stimulus similarity. *Psychological Review*, **96**, 433-458.

Eriksen, C. W. (1952). Location of objects in a visual display as a function of the number of dimensions on which the objects differ. *Journal of Experimental Psychology*, **44**, 56-60.

Estes, W. K. (1972). Interactions of signal and background variables in visual processing. *Perception & Psychophysics*, **12**, 278-286.

Evans, R. J. (1993). *Image quality and the display modulation transfer function: experimental findings*. AL/HT-TR-1993-0131, Mesa, AZ: Armstrong Laboratory.

Geiselman, R., Landee, B. M., & Christen, F. G. (1982). Perceptual discriminability as a basis for selecting graphic symbols. *Human Factors*, **24**, 329-337.

Ginsburg, A. P. (1986). Spatial filtering and visual form perception. In K. R. Boff, L. Kaufman, & J. P. Thomas (Eds), *Handbook of Perception and Human Performance*. (pp. 34.1-34.41). New York: Wiley & Sons.

Granlund, G. H. (1972). Fourier preprocessing for hand print character recognition. *IEEE Transactions on Computers*, **C-21**, 195-201.

International Hydrographic Organization (1995). *Appendix 2, Annex A of IHO ECDIS Presentation Library (2nd ed.), hard copy addendum*. IHO Special Publication No. 52. Monaco: International Hydrographic Organization.

Kleiss, J. A. (1995). Visual scene properties relevant for simulating low-altitude flight: A multidimensional scaling approach. *Human Factors*, **37**, 711-734.

Kuennapas, T. (1967). Visual memory of capital letters; multidimensional ratio scaling and multidimensional similarity. *Perceptual & Motor Skills*, **25**, 345-350.

Kuennapas, T. & Janson, A. J. (1969). Multidimensional similarity of letters. *Perceptual & Motor Skills*, **28**, 3-12.

Maddox, M. E. (1979). Two-dimensional spatial frequency content and confusion among dot matrix characters. *Proceedings of the Human Factors Society 23rd Annual Meeting*, 384-388.

Medin, D. L., Goldstone, R. L., & Gentner, D. (1993). Respects for similarity. *Psychological Review*, **100**, 254-278.

Nagy, A. L. & Cone, S. M. (1996). Asymmetries in simple feature searches for color. *Vision Research*, **36**, 2837-2947.

Paramei, G. V., Izmailov, C. A., & Sokolov, E. N. (1991). Multidimensional scaling of large chromatic differences by normal and color-deficient subjects. *Psychological Science*, **2**, 244-248.

Podgorny, P. & Garner, W. R. (1979). Reaction time as a measure of inter- and intraobject similarity: letters of the alphabet. *Perception & Psychophysics*, **26**, 37-52.

Quinlan, P. T. & Humphreys, G. W. (1987). Visual search for targets defined by combinations of color, shape and size: An examination of the task constraints on feature and conjunction searches. *Perception & Psychophysics*, **41**, 455-472.

SAS Institute Inc. (1992). *SAS/STAT® Software: Changes and Enhancements, Release 6.07*. SAS® Technical Report P-229, Cary, NC: SAS Institute Inc.

Tomonaga, M. & Matsuzawa, T. (1992). Perception of complex geometric figures in chimpanzees (Pan troglodytes) and humans (Homo Sapiens): analyses of visual similarity on the basis of choice reaction time. *Journal of Comparative Psychology*, **106**, 43-52.

Treisman, A. M. & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology*, **12**, 97-136.

Treisman, A. M. & Gormican, S. (1988). Feature analysis in early vision: Evidence from search asymmetries. *Psychological Review*, **95**, 15-48.

Van Selst, M. & Jolicoeur, P. (1994). A solution to the effect of sample size on outlier elimination. *Quarterly Journal of Experimental Psychology*, **47**, 631-650.

Young, F. W. (1987). *Multidimensional Scaling: History, Theory, and Applications*. R. M. Hamer (Ed). Hillsdale, NJ: Lawrence Erlbaum Associates.

Zahn, C. T. & Roskies, R. Z. (1972). Fourier descriptors for plane closed curves. *IEEE Transactions on Computers,*, **C-21**, 269-281.

APPENDIX A

Cartesian Coordinates for Symbol Set

The names in brackets are the ECDIS symbol name for the symbols used in this study. The values are given in arbitrary units.

a (bcnsaw13.sym): -100 200, 100 200, 100 -200, -100 -200, -100 200.

b (bcnspp12.sym): -100 -300, 100 -300, 100 100, 0 300, -100 100, -100 -300.

c (boylat13.sym): 187 190, 187 -249, -246 190, 187 190.

d (boylat23.sym): -251 148, -99 -250, 277 -250, 151 148, -251 148.

e (boysaw12.sym): -200 0, -194 -52, -174 -100, -142 -142, -100 -174, -52 -194, 0 -200, 51 -194, 100 -174, 141 -142, 173 -100, 193 -52, 200 0, 193 51, 173 100, 141 141, 100 173, 51 193, 0 200, -52 193, -100 173, -142 141, -174 100, -194 51, -200 0.

f (buisgl01.sym): -132 -132, 118 -132, 118 118, -132 118, -132 -132.

g (clrlin01.sym): -163 200, 0 -407, 162 200, -163 200.

h (dnghilit.sym): -294 293, 293 293, 293 -294, -294 -294, -294 293.

I (hulkes01.sym): -250 90, -250 -100, -254 -97, -191 -129, -107 -141, -32 -141, 50 -125, 128 -85, 203 -41, 234 -4, 156 53, 81 90, 21 112, -60 125, -91 125, -141 118, -250 93.

j (lightdef.sym): 0 350, -125 -225, -125 -263, -113 -300, -94 -319, -63 -344, -25 -350, 0 -350, 31 -350, 62 -338, 87 -313, 106 -275, 112 -250, 106 -194, 0 350.

APPENDIX B

Table B1: Coordinates for each dimension for the one, two, and three dimensional fits based on the similarity ratings.

Symbol	1:1	2:1	2:2	3:1	3:2	3:3
a	0.12	0.00	0.36	0.50	0.25	0.88
b	1.11	0.98	-0.44	1.25	-0.66	0.45
c	0.49	0.75	1.33	0.18	1.31	-1.26
d	-0.17	-0.39	0.88	-0.46	1.05	0.23
e	-1.80	-1.56	-1.38	-1.69	-1.48	0.03
f	-0.30	-0.87	0.43	-0.64	0.31	1.26
g	0.94	1.39	0.62	1.18	0.49	-1.24
h	-0.29	-1.01	0.97	-0.24	1.08	1.47
i	-1.49	-0.63	-1.65	-1.31	-0.85	-1.38
j	1.40	1.34	-1.05	1.24	-1.50	-0.44

Table B2: Coordinates for each dimension for the one, two, and three dimensional fits based on the response times in the visual search task.

Symbol	1:1	2:1	2:2	3:1	3:2	3:3
a	0.67	0.45	-0.94	0.50	-1.20	0.72
b	1.17	0.95	-0.44	-0.46	-0.73	1.01
c	0.24	0.69	1.23	0.85	1.25	0.75
d	-0.49	-0.16	1.41	-0.51	1.72	-0.23
e	-1.60	-1.50	0.07	0.47	0.65	-1.62
f	-0.16	-0.45	-1.64	0.44	-1.50	-1.06
g	0.94	1.11	-0.44	-0.28	0.48	1.32
h	-0.92	-1.22	1.24	-1.72	0.01	-1.20
i	-1.25	-1.20	-0.82	1.91	0.06	-0.51
j	1.41	1.34	-0.58	-1.19	-0.75	0.82

Unclassified

SECURITY CLASSIFICATION OF FORM
(Highest classification of Title, Abstract, Keywords)

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g., Establishment sponsoring a contractor's report, or tasking agency, are entered in section 12.) Defence and Civil Institute of Environmental Medicine 1133 Sheppard Ave. W., P.O. Box 2000, North York, Ont. M3M 3B9	2. DOCUMENT SECURITY CLASSIFICATION (overall security classification of the document including special warning terms if applicable) Unclassified/Unlimited

3. DOCUMENT TITLE (the complete document title as indicated on the title page. Its classification should be indicated be the appropriate abbreviation (S, C, R or U) in parentheses after the title.)
Measures of the Discriminability of Symbol Shapes (U)

4. DESCRIPTIVE NOTES (the category of the document, e.g., technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)
Technical repor

5. AUTHOR(S) (Last name, first name, middle initial. If military, show rank, e.g. Burns, Maj. Frank E.)
McFadden, Sharon, Bauer, Ben and McManus, Kelly

6. DOCUMENT DATE (month and year of publication of document) December 1997	7.a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.) 39	7.b. NO. OF REFS. (total cited in document) 32

8.a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant)	8.b. CONTRACT NO. (if appropriate, the applicable number under which the document was written)
9.a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.) DCIEM No. 97-R-61	9.b. OTHER DOCUMENT NO.(S) (any other numbers which may be assigned this document either by the originator or by the sponsor.)

10. DOCUMENT AVAILABILITY (any limitation on further dissemination of the document, other than those imposed by security classification)

- x Unlimited distribution
- ☐ Distribution limited to defence departments and defence contractors; further distribution only as approved
- ☐ Distribution limited to defence departments and Canadian defence contractors; further distribution only as approved
- ☐ Distribution limited to government departments and agencies; further distribution only as approved
- ☐ Distribution limited to defence departments; further distribution only as approved
- ☐ Other

11. ANNOUNCEMENT AVAILABILITY (any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (10.) However, where further distribution (beyond the audience specified in 10) is possible, a wider announcement audience may be selected.)
Unlimited

12. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.)

DSIS DCD03
HFD 09/94

Unclassified

SECURITY CLASSIFICATION OF FORM
(Highest classification of Title, Abstract, Keywords)

Unclassified

SECURITY CLASSIFICATION OF FORM
(Highest classification of Title, Abstract, Keywords)

13. ABSTRACT (a brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual).

The increase in the complexity of computer-based graphical information systems has resulted in a requirement for large symbol sets. To ensure that decisions are made with speed and accuracy, it is important for the symbols in such systems to be discriminated consistently and reliably. Studies on symbol discrimination usually find that discrimination is a function of the number and kinds of dimensions along which the symbols vary. However, the critical dimensions often vary from study to study. Some of this variability could be due to the wide range of conditions and methodologies used across studies. If this is the case, it is important to understand how different conditions and tasks influence the perceptibility and discriminability of symbols. The study reported in this paper addressed this problem. It compared the characteristics used in assessing the similarities of a set of symbols in a rating task with those used in picking out symbols in a visual search task. The former task is similar to the process used by a designer in selecting symbols while the latter is an important component of the actual tasks that an user carries out in locating information on a display.

Participants rated the similarity of ten geometric shapes using a paired-comparison task. Discriminability of these shapes was then examined using a visual search task where participants enumerated the number of occurrences of a particular target shape found in a display of distractors. The results were submitted to correlation and multidimensional scaling (MDS) analysis to examine the relationship between the similarity ratings and the visual search task. Based on the correlation analysis, subjective assessment can predict when two symbols will be highly discriminable. However in some cases, symbols rated as similar proved highly discriminable in the search task. The results of the MDS analysis suggested that, in the similarity rating task, participants differentiated the symbols primarily on their overall geometric shape. However in the visual search task, participants appeared to use other dimensions such as vertical height and symmetry in discriminating the symbols. These findings in conjunction with the results of other researchers suggest that context and task both may influence the features used in discriminating symbols. Suggestions are made for additional research that would evaluate the relevance of these two factors more thoroughly.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible, keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

shape coding
paired comparisons
visual search
multidimensional scaling
methodology
displays